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ABSTRACT

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Processing Time and Question Type in the Comprehension of Compressed Speech with Adjunct Pictures

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Abstract

The effect of adding time for processing compressed speech and the effects of questions that gave adjunct pictures either a redundant or a contextual function were determined. Subjects were 144 fourth- and fifth-grade students assigned randomly to 24 groups. They listened individually to a 20-sentence story at either 225 or 300 words per minute (wpm). Also, they either looked at pictures as they listened or only listened. Questions in cued recall gave the pictures either a redundant or a contextual function. Alpha was set at .05. Increase in recall was significantly greater at the higher than at the lower wpm rate when pause time was added between sentences as well as when pictures were added to the story. Questions that made pictures redundant improved recall, whereas pictures that made them contextual did not. The results with respect to pause time supported several prior studies. The results with respect to the use of redundant pictures suggested that pictures can preclude a reduction in comprehension at higher wpm rates.

Processing Time and Question Type in the Comprehension of Compressed Speech with Adjunct Pictures

Information is processed primarily by either listening or reading. Reading is often thought of as the primary mode of communication. However, listening is also an important mode. Furness (1971) agreed with Early (1971) that students at all age levels spend a larger proportion of their time in and out of school in listening than in reading. In addition, Duker (1971) summarized the results of several studies showing that, "About 60% of the elementary day is spent in listening of one sort or another" (p. 103). Listening is involved in many kinds of learning. Various kinds of teaching methods involve speaking and listening as the primary mode of communication--for example, lectures, discussions, peer learning, certain simulation games, etc. The use of audio materials in classrooms has increased in recent years with the greater availability of educational technology, leading to even more emphasis on listening. Moreover, mass communication via radio and television has made listening more important to every person. Recently, a number of new technological developments has increased further the incidence of speech communication. Examples are talking calculators and clocks and special devices to teach elementary skills to children. Pisoni (1982) has been doing research concerned with the

production of synthetic speech by computers and anticipates that such research will lead to more natural communication between people and machines.

In spite of the importance of listening in communication, listening is ordinarily less efficient than reading. Whereas in reading one can take in entire phrases and even sentences in a single glance, in listening one must respond to single words in sequence. As a consequence, listening proceeds much more slowly than reading. In reading, people often "scan" material with which they are familiar, achieving very high words-per-minute rates.

A number of technological developments over the past 30 years has made listening considerably more efficient when the material listened to has been tape recorded. The general term for the process that increases efficiency is "time-compressed speech." Time-compressed speech--also called compressed speech-- was anticipated in a sense by Miller and Licklider (1950). Taking advantage of the knowledge that normal speech is redundant, that is, that speech contains more information than is necessary for its being understood, they periodically eliminated portions of recorded speech. This was accomplished by having an automatic switch turn the speech of and off. When the number of interruptions per second was 100, they found that the speech was understood almost perfectly. Their procedure was modified by Garvey (1953) who eliminated small portions of an audio tape on which a number of unrelated words had been recorded, using a razor blade, and spliced

the remaining portions together. He had people listen to the words one at a time. He found that the intelligibility of the words was unaffected until they had been shortened to one-third of their original length. This "chop-splice" method was the first one used for producing compressed speech. Fairbanks, Everitt, and Jaeger (1954) described an electro-mechanical device that produced materials very much like those produced by Garvey. Their procedure as well as Garvey's resulted in speech that retained the original voice frequencies. Other such electro-mechanical devices were produced both in the United States and in Germany over the next two decades. These devices were characterized by their bulk, high cost, and complexity. More recently, a new type of compressor has appeared on the market that is portable, inexpensive, and simple. This compressor has been made possible through the use of large-scale integrated circuits that are characteristic of modern technology. Thus, it is now feasible for individuals to have their own personal speech compressor, just as it is feasible for them to have their own pocket calculator. If a learner has purchased or prepared tape recorded educational material, by playing back this material using a modern speech compressor, he can continually adjust the speed at which he listens to suit his own needs.

The development of speech compressors and the consequent option on the part of the listener to listen to recorded materials at various rates has prompted a number of studies of variables affecting the intelligibility of individual words as well as the comprehension of connected discourse. A substantial amount of this research was described at three national

compressed speech conferences held in 1966, 1969, and 1975. A review of much of this research was published by Foulke and Sticht (1969). An extensive anthology and annotated bibliography in three volumes was published by Duker (1974). Much of the research that has been done is dependent on studies done earlier involving speech at normal rates. Therefore, such concepts as that of information processing have been useful in compressed speech research. No attempt will be made here to summarize all of the research concerned with compressed speech, but rather only the research that has led up to the present study.

The comprehension of discourse has been a primary empirical domain of concern to cognitive theorists (e.g., Just and Carpenter, 1977). Most of the research has been concerned with reading, although it is not uncommon for listening to discourse to be included within theoretical formulations (e.g., Kintsch, 1977). The fundamental variable that defines time-compressed speech is the words-per-minute (wpm) rate at which recorded material is presented. As would be expected, given a sufficiently high wpm rate, comprehension declines drastically. Foulke and Sticht (1969) wrote, "The increase in rate at which comprehension declines beyond 275 wpm suggests that when a certain critical word rate is reached, a factor in addition to signal degradation [i.e., distortion introduced by the process of time compression]begins to determine the loss of comprehension. The understanding of spoken language implies the continuous registration, encoding, and storage

of speech information, and these operations require time (italics added). When the word rate is too high, words cannot be processed as fast as they are received, with the result that some speech information is lost" (p. 60). Hughes and Foulke (1975) found that one effect of signal degradation is to slow down the processing of speech information, thereby contributing to the total time required for the understanding of spoken language. In their experiment, highly compressed isolated words were identified less rapidly by listeners, and it was concluded that this result supported further the position of Foulke and Sticht (1967) that the decrement in comprehension of connected speech as wpm rate increases is at least in part a function of the increasingly limited time available to the listener to process speech information. This result is consonant with Aaronson's (1967) conclusion based upon the results of several studies that "experimental evidence indicates that processes continue to occur after the physical stimulus presentation--either auditory or visual--is terminated. Interference with or termination of these post-presentation perceptual processes can lead to decreased recall accuracy" (p. 136). An example of these studies was one done by Aaronson (in Aaronson, 1967, p. 134). She compressed spoken digits in sequences of seven but left the rate of their presentation unchanged. Recall of the sequences was more accurate for the compressed than for the original digits. She presumed that providing more silent time allowed more adequate perceptual processing and hence more accurate

recall.

Chodorow (1979) has made use of time-compressed speech in an attempt to detect and differentiate lexical and syntactic processing when isolated sentences rather than isolated words or digits are used. In reviewing prior research, he drew attention to the conclusion that lexical processing occurs only in close proximity to a given word, while syntactic processing may be "strung out." He reasoned that he could track the processing of an auditory sentence occurring after that sentence had been completed by following the sentence with an auditory word list having its onset after various lengths of pauses between the conclusion of the sentence and the onset of the word list. Presumably, with a shorter pause, processing of the sentence would tend to compete with listening to the subsequently presented word list, and both the recall of the sentence and the recall of the word list would show decrements. He was especially interested in such effects resulting either from (a) an ambiguous word in a sentence or from (b) syntactic complexity. Also, he reasoned that in using time-compressed speech where the wpm rate is high, presumably the processing of a concluded sentence would be even more likely to continue during the period when the word list was being presented. With an ambiguous word in each sentence, he found that a decrement in recall of the ambiguous word resulted from "premature truncation of some ambiguity resolution procedure" (p. 100). Although a longer pause between sentence and word list

improved performance, this effect was not statistically significant. However, with a variation in syntactic complexity (in his words, structural indeterminacy), it was found that with more complex sentences, a shorter pause time produced a significant decrement in recall of the word list, consistent with the view that with increasing complexity, processing continues longer after the sentence is over. Also, a longer pause improved sentence recall following less complex sentences when they were compressed, but not following more complex sentences. Apparently the more complex sentences required more pause time than the longer of the two values of pause time that were used.

Overmann (1971) also investigated the effect of introducing pauses in compressed speech, but she introduced them between phrases and sentences in discourse rather than in relation to single sentences. She divided the time saved in the process of compression among phrase and sentence junctions, thus replacing the processing time lost through compression. The result was that performance was improved significantly compared with compression without such replacement. However, there was still some decrement in performance in relation to the control (normal rate) condition. Presumably, this remaining decrement was due to both signal degradation and to consequent insufficient time for identifying individual words, as suggested by Hughes and Foulke (1975).

The results of Aaronson (in Aaronson, 1967), Chodorow (1979), and Overmann (1971) suggest that providing additional processing time improved recall of either a sequence of digits, an isolated sentence, or discourse.

There is evidence that the amount of processing time needed for adequate retention following the brief presentation of pictures is approximately 1 sec and under some conditions even less (Sheikhian, Fleming, & Hughes, 1975). Presumably, knowledge about such processing requirements in discourse can provide ways of improving its comprehension.

Even though an adequate amount of processing time is available at sentence boundaries, the unintelligibility of individual words may interfere with adequate comprehension of discourse. As indicated above, this may be both because of a degraded signal per se and because such a signal results in an inordinate consumption of time even if it is finally identified. It will be recalled that Chodorow (1979) pointed to evidence that lexical processing occurs only in close proximity to a given word. On that basis we might speculate that words that require an inordinately long time for identification will simply be missed. However, this may not happen if redundancy is increased by some means, for Sticht (1969) found evidence that signal distortion is of less consequence when redundancy is increased. Levin and Lesgold (1978) have reviewed research concerned with the presentation of pictures that are considerably redundant with respect to concurrent auditory discourse at normal wpm rates. A number of studies has shown that young children's comprehension in these circumstances is consistently improved. Hughes, Langdon, and Kim (1981) measured such an effect at various wpm rates and obtained results confirming those described by Levin and Lesgold (1978). They had speculated that the use of redundant pictures would facilitate comprehension to an even greater degree at higher wpm rates.

This speculation was based upon Hughes and Foulke's (1975) finding that more highly compressed words are identified more slowly. It seemed likely to them that the redundant information in pictures would increase the probability that critical words in the discourse would be identified within the relatively brief amount of time during which this would be possible. They spoke of the possible replacement by redundancy in pictures of the redundancy in discourse that was lost through time compression. Their results were in the predicted direction in three experiments, but they were not statistically significant.

An alternative view to that taken by Hughes, Langdon, and Kim (1981) is that a picture may itself transmit information that allows the viewer to answer a question that has been composed to test a listener's comprehension of a sentence which that picture accompanies. That is to say that the picture may not act to make an auditory sentence more comprehensible, but instead may transmit information contained in that sentence while the sentence itself remains incomprehensible. In the Hughes et al. (1981) study, some of the third grade children listened to discourse at a very high rate, namely, 375 wpm. The usual conditions of listening to the discourse alone and listening to discourse accompanied by pictures were used, but also the pictures that had been used previously only in conjunction with the recorded discourse were for the first time presented alone, at durations that were the same as when they were presented along with the discourse. The results were that subjects who saw the pictures alone performed equally as well as those who both saw the pictures and listened to the discourse at 375 wpm.

However, those who only listened to the discourse performed at such a low level that they seemed to be understanding virtually nothing of what they heard. This result suggests that the pictures may, indeed, have been primarily transmitting information directly rather than acting to make the discourse understandable. Of course, at the rate of 375 wpm it could be that the discourse could not have been made understandable by any means whatsoever. In the present study, rates lower than 375 wpm were used, and therefore it seemed necessary to include the condition of presenting the pictures alone.

Further, we might say that if the character of the pictures were such as to provide a context for the information contained in the discourse rather than to provide that same information, then perhaps the discourse would be made more comprehensible, making a claim for the pictures' bringing about greater comprehension of the text more believeable. In research discussed by Chodorow (1979), subjects' interpretation of a lexically ambiguous sentence could be biased toward either sense of the ambiguity by providing an appropriate context sentence to one of their ears while they listened to the ambiguous sentence in the other ear. The use of a picture that provides context for a sentence is somewhat analogous to Chodorow's procedure.

The decision was made to attempt to change the questions for some subjects in such a manner as to make the pictures contextual rather than redundant--that is, to change them such that it seemed likely that they could not be answered on the basis of seeing the pictures but could be answered on the basis of hearing the discourse. In some instances it was

not possible to make such changes. However, enough such changes could be made to make it seem reasonable to incorporate as a fourth independent variable the nature of the relationship between the discourse and the pictures. That is, the pictures would function either as a source of redundant information with respect to the sentences or else the pictures would function as a context for the sentences, with the presumption that in either case the sentences would become more comprehensible as a result. However, it seemed likely that redundant pictures would improve comprehension more than contextual pictures would. A redundant picture provides information that may not have been transmitted successfully by a time-compressed sentence, while a contextual picture only increases the probability that the sentence transmits its information. Guttman, Levin, and Pressley (1977) found results consonant with this conjecture when kindergarten children were subjects but not when second and third graders were subjects. Their redundant ("complete") pictures depicted a critical object while their contextual ("partial") pictures depicted only the environment of the object. An experiment with similar results was done by Pressley, Pigott, and Bryant (1982). Of course, in the present experiment, higher-than-normal wpm rates were used, and even for older children it seemed likely that redundant pictures would improve comprehension more than contextual pictures would in view of the redundant pictures' providing information that may have not been transmitted successfully at the higher rates.

As indicated in the preceding paragraph, some of the questions were to be changed to give the pictures a contextual function rather than a redundant function. The question arose as to whether the two forms of the questions were of equal difficulty. If they differed in difficulty, then difficulty and function of the two forms would be confounded. A determination of the relative difficulty of these two forms was made during the course of the experiment, as will be described later.

The purpose of the present research was to explore the extent to which the usual decrease in the comprehension of recorded discourse by young children as wpm rate of the discourse increases is less as a result of (a) adding pause time at sentence boundaries, (b) providing redundant pictures, and (c) providing contextual pictures.

Method

Subjects

Participants were 144 fourth- and fifth-grade students in local and area schools. The participants were randomly assigned in equal numbers to each of 24 experimental conditions resulting from the combination of two pause times, two rates, two presentation conditions, and two question types, and to eight control conditions where only the pictures were presented.

Apparatus

The experiment was conducted at each of four schools. The experimental room was a room that was made available at each school. Each room provided a quiet and private environment.

A Dukane Micromatic II Sound Filmstrip Projector was used to project filmstrips. The discourse was recorded on Maxell cassette tapes. Two sets of high quality earphones together with a junction box were used to allow both the subject and the experimenter to listen to a story.

Materials

The discourse, pictorial, and test materials of Bender and Levin (1978) were used. The discourse and pictorial materials consist of a 20-sentence, fictitious story titled "Joseph, the Border Guard" together with 20 line drawings with watercolor embellishment, one for each of the sentences. For each sentence there is a question that can be answered with a word or a short phrase. These questions correspond to a level of comprehension of discourse described by Perfetti (1977) as questions that "require information based on a semantic-syntactic analysis of the sentence and are the kind of 'literal questions' (referential, not inferential) that test construction is familiar with" (p. 22). For example, the first sentence is, "Once upon a time there was a small kingdom ruled by a king who lived on a hill outside of the kingdom." However, eight of these questions were changed for some subjects to create contextual pictures as opposed to redundant pictures. For instance, subjects were presented a picture of a castle on a hill outside of a kingdom. Subjects in the redundant pictures condition were asked, "Where did the king live?" In the contextual pictures condition, subjects were asked, "Who lived on the hill outside of the kingdom?" The picture did not show the king but only the place

where he lived. The first question made the picture redundant since it required the subject to provide information in the picture (place lived). The second question made the picture contextual since it required the subject to provide information not in the picture (who lived in that place). Rules were adopted to define correct responses to the questions. Practice materials consist of a three-sentence story together with three line drawings with watercolor embellishment. The sentences had been tape recorded for use in the Hughes et al. study, with broadcast quality at 150 wpm by a professional reader. This tape was compressed to each of two rates, 225 and 300 wpm, using a Varispeech II Speech Compressor. Following each recorded sentence, there was a single 50 cps tone on the tape for the experimental conditions where the pause was 0 sec. This tone advanced a filmstrip consisting of the 20 line drawings to the next frame. However, for the experimental conditions where the pause was 4 sec, following each recorded sentence there were two successive 50 cps tones on the tape. The two tones were separated by 4 sec in terms of tape transport time. Each of these tones advanced the filmstrip projector by one frame. A second filmstrip consisting of the 20 line drawings was constructed such that there was a blank frame between successive drawings. In this way the first of the pair of 50 cps tones advanced the filmstrip to a blank frame and thus removed the current drawing, while the second tone advanced the filmstrip to the next drawing. The filmstrip projector is constructed such that the 50 cps tone is inaudible.

Procedure

The projector was set up at a distance of 5.5 ft (1.7 m) from a wall of the experimental room to produce a 12 x 18 in (30 x 45 cm) image. The image was projected on a piece of 22 x 28 in (56 x 71 cm) white cardboard that was mounted on the wall. Subjects participated one at a time. Order of experimental conditions was random with the restriction that there were six replications of each condition. The subjects were seated on the right side of the projector and were 7 ft (2.1 m) away from the screen. The subjects were given instructions in keeping with experimental conditions to inform them that they would be listening to a story, with or without accompanying pictures, or would be watching a series of pictures that in themselves tell a story, and that afterwards they would be asked some questions about it. They were given practice materials, including questions, under the same condition to which they had been assigned. After the instructions and examples had been provided the subjects, they listened to the sentences, with or without accompanying pictures, or saw the pictures alone, and then were asked questions. Questions were asked and answered orally in the same order as the sentences. The experimenter wrote down the answers on answer sheets. When each subject finished, s/he was asked not to talk about the story with friends until the study had been completed at that particular school.

Design

The four independent variables--pause time, wpm rate, presentation condition, and question type--were combined in a 2x2x2x2 factorial design.

The reason that the design implies only two values of the presentation condition variable is that the condition of presenting pictures alone was treated as a control condition for the purpose of comparing the amount of information transmitted by the pictures alone with the amount transmitted by the discourse alone, in a separate analysis. A second control analysis was done to determine whether the two sets of eight questions each, that differed in their function of making the pictures either redundant or contextual, were of equal difficulty. For this purpose, the data from subjects who only listened to the discourse was used. A third and final control analysis was done to verify that the questions designed to give the pictures different functions did, indeed, give them those functions. Data from subjects who had seen the pictures but had not listened to the discourse were used. Clearly, the redundant questions should result in more correct answers than the contextual questions because the redundant questions pertained to information contained in the pictures, while the contextual questions did not. The level of significance adopted for all statistical analyses was .05.

Results

The results will be described in terms of performance on the 8 questions of the original 20 in order that direct comparisons involving the redundant and the contextual functions of the pictures may be made. Also, as it turned out, results involving all 20 of the questions were equivalent to those involving only the 8 questions and would provide only redundant information.

Table 1 shows the mean number of correct answers out of eight for the various combinations of values of the four independent variables. The results of an analysis of variance for these data are shown in Table 2.

Insert Table 1 and Table 2 about here

The main effect of pause time was not significant (Table 2). The mean number of correct answers for a 4-sec and a 0-sec pause were, respectively, 4.89 and 5.04. However, a question of greater interest was whether as the rate of discourse increased, adding pause time resulted in less loss in comprehension than when pause time was not added. This question corresponds to the rate-by-pause-time interaction, which was significant (Table 2). As shown in Table 3, the nature of that interaction was that, whereas with a 4-sec pause the decrease in mean number of correct answers as rate increased was 1.37, with a 0-sec pause the decrease was 2.75. A simple main

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Insert Table 3 about here

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effect test of the significance of each of these two differences showed that each was significance (F = 8.97 and 36.16, respectively). Thus, with increasing rate, the 4-sec pause resulted in a significantly smaller loss in comprehension than did the 0-sec pause. Pause time was thus shown to be of consequence in spite of not being a significant

main effect.

Unlike the main effect of pause time, the main effect of wpm rate was significant (Table 2). The mean numbers of correct answers for the two wpm rates of 225 and 300 were 6.00 and 3.94, respectively. As just described, wpm rate interacted with pause time. In addition, rate interacted with presentation condition (Table 2). As shown in Table 4, the nature of that interaction was that, whereas the increase in mean number of correct answers at the lower rate when pictures were added was 1.08, the increase at the higher rate was 2.38. Thus, the

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Insert Table 4 about here

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facilitating effect of pictures was approximately twice as great at the higher rate as at the lower rate. Each of these increases was significant (F = 5.58 and 27.08, respectively), in keeping with the significance of the main effect of presentation condition (Table 2). The mean numbers of correct answers for the discourse-alone condition and the discourse-and-pictures condition were 4.15 and 5.84, respectively.

Although the main effect of question type was not significant, it interacted with presentation condition (Table 2). Table 5 shows the nature of that interaction. Improvement in mean performance was

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Insert Table 5 about here

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about four times as great in the case of questions that made the pictures redundant, 2.75, as in the case of questions that made the pictures contextual, .71. The first of these two mean differences was significant (F = 36,16), while the second was not significant (F = 2.41). Thus, adding pictures that had a redundant function was facilitative, while adding pictures that had a contextual function was not.

It will be recalled that three analyses were done for control purposes. In the case of the presentation-condition variable, a question of considerable interest concerns the extent to which subjects were able to answer the questions after having seen the pictures without having heard the discourse. As pointed out earlier, the pictures-alone condition may therefore be characterized as a control condition. The mean number of correct answers out of a total of eight for subjects who listened to the narrative was 4.21, while the mean number for subjects who saw the pictures was 3.29. The difference between these means was significance (F = 6.86). However, it is clear that performance by subjects who saw the pictures was substantial.

The second control question was whether the two sets of eight questions each, that differed in their giving the pictures the function of being either redundant or contextual, were of equal difficulty. To answer this question, an analysis was done using data from those subjects who only listened to the discourse. For redundant questions, the mean number of correct answers was 3.75, while for contextual

questions, the mean was 4.46. The difference between these means was not significant ($F = 2.18$). Thus, it appeared that the intended function of the pictures, redundant or contextual, was not confounded with the variable of level of difficulty.

The third and final control question was whether the redundant and contextual questions actually resulted in the pictures' having these respective functions. To answer this question, an analysis was done using data from those subjects who only saw the pictures. For redundant questions, the mean number of correct answers was 4.83, while for contextual questions, the mean was 2.21. Thus, the questions appeared to have given the pictures their intended functions, in general. The failure of the mean number of correct answers for contextual questions to be equal to zero would seem to have been due to subjects' prior knowledge and to lack of independence of the content of the various pictures.

Discussion

One of the more notable results of the present study is that all four of the independent variables were involved in one or more significant interactions, whereas only two of the main effects were significant. These two effects, wpm rate and presentation condition, were each involved in two of the three interactions. Thus, under the conditions of the present study, answers about the effect of individual independent variables must be qualified with respect to the specific values of one or more other independent variables.

It will be recalled that several studies were described earlier that were concerned with the general hypothesis that under some circumstances people continue to process verbal stimuli after these stimuli have been terminated. It was these studies that led to the investigation in the present experiment of the effect of introducing additional processing time between successive sentences in connected discourse. The results of these prior studies were confirmed in the present study but only under certain conditions, as implied in the statements above about interactions between the independent variables. The present study was related procedurally more to some than to others of the prior studies, but from the point of view of the general hypothesis identified above, it would seem to be related to all of them equally. In the Hughes and Foulke (1975) study, there was evidence that the processing of individual words to be identified continues for some time after the words have been presented, when the words are highly compressed. This evidence was based upon longer times taken to identify the words at higher values of compression. In the study described in Aaronson (1967) there was evidence that each of a series of numerical digits continues to be processed after its presentation. This evidence was based upon greater recall of the digits after they had been time compressed to create additional time between them. In the Chodorow (1979) study, there was evidence that the processing of a time-compressed sentence continues after its presentation. This evidence was based upon greater recall of the sentence as well as greater recall of a list of words that followed the sentence when the

interval of time between the end of the sentence and the beginning of the list of words was longer. Finally, in the Overmann (1971) study, there was evidence that the processing of phrases and sentences in time-compressed discourse continues after their termination. This evidence was based upon greater comprehension of the discourse when the time saved through time compression was distributed at phrase and sentence boundaries. It will be recalled that in the present study there was evidence that the processing of sentences continues after their completion inasmuch as at the higher wpm rate, the mean number of correct answers was significantly less with a 0-sec pause than with a 4-sec pause between sentences, while at the lower wpm rate, the effect of length of pause was not significant. This result in the present study is unique in that a rate by pause time interaction was found, although it seems that this is so only because rate and pause time had not been manipulated independently with the exception of the Hughes et al. (1981) study where a similar although non-significant result occurred. It is of some interest to compare the present study with other studies from the point of view of experimental design.

In the Hughes and Foulke (1975) study, the procedure was such that neither rate nor pause time was involved as a variable. Words were presented at fixed intervals, several seconds apart, and the identification of a word almost invariably would be made long before the end of the interval. The only sense in which rate could be said to be involved was that the words had been time compressed in a manner

corresponding to what would have been various wpm rates if discourse had been the material that was compressed. This might be described as a momentary rate. The only sense in which a pause was involved was that the dependent variable was reaction time in identifying the words, a "pause" on the part of the subject--that is, the subject needed a longer "pause" when rate was higher.

In Aaronson's (in Aaronson, 1967) study, rate of occurrence of the digits was fixed. Compression of the digits improved performance, the interpretation being that more time was left for processing each individual digit before the next one was presented. If rate is equated with amount of compression (momentary rate), in this procedure rate and "pause time" were positively and perfectly correlated.

In Chodorow's (1979) study, it would have been possible to combine rate and pause time factorially, but this was not done. He used normal and twice normal wpm rates of presentation of sentences but used two values of pause time only at the twice normal rate.

In Overmann's study, rate and pause time were positively and perfectly correlated as in Aaronson's (in Aaronson, 1967) study. She compared comprehension of discourse with and without added pause time at each of three rates, but she was unable to evaluate rate and pause time independently because at higher rates, pause times were longer.

The finding in the present study that pictures improved comprehension more at a higher wpm rate than at a lower one is of

considerable interest. If the present finding is confirmed in further research, it may have importance not only in the context of compressed discourse but also in other adverse listening conditions. It is interesting to speculate how Overmann's results might have been affected by the use of pictures. At two lower values of compression she found that the addition of pause time between phrases and between sentences resulted in a level of performance not significantly lower than that of subjects who listened to the original (uncompressed) version of the discourse. However, at a higher value of compression, performance was significantly lower. The results of the present study suggest that with pictures available to this latter group, performance might have been maintained at the level of that achieved by subjects who listened to the original version.

The finding in the present study that adding redundant pictures to discourse improved comprehension more than adding contextual pictures was similar to that of Guttman, Levin, and Pressley (1977), obtained with kindergarten children and to that of Pressley, Pigott, and Bryant (1982), obtained with 3- and 4-year-old children. In the Pressley et al. (1982) study, adding contextual pictures did not improve comprehension, while in the Guttman et al. (1977) study, contextual pictures improved comprehension in third-grade students but not in kindergarten and second-grade students. It will be recalled that contextual pictures did not improve comprehension in the present study. There is not a consistent relation in these

studies, taken together, between the effect of contextual pictures and chronological age. It would seem that either chronological age is not a relevant variable or else that materials, procedures, etc. varied among the studies in a way to obscure any such relationship.

The manner in which pictures were given a contextual function in the present study is somewhat unsatisfactory. It necessitated confounding the function of the pictures and the very content of the questions. Although the outcome of an analysis suggested that changing the content of the questions did not change their difficulty, a more direct way of giving pictures a redundant or a contextual function would be preferred, and this would also allow a comparison of the functions of 20 pictures instead of just 8. Rather than changing the questions, a new set of pictures could be created that were contextual rather than redundant with respect to the discourse.

The finding that subjects who only saw the pictures answered a substantial portion of the questions makes it evident that the improvement of performance through the use of pictures may not be due at all to the pictures' making the discourse more comprehensible. However, it is conceivable that whereas some pictures transmitted the relevant information independently of the discourse, other pictures did function in a way to make the discourse more comprehensible. Also, it is conceivable that a given picture may have functioned in a different way for different subjects. The issue can be resolved only by designing pictures that do not transmit the information necessary for answering the questions.

Finally, it would seem of interest to modify the present procedures in such a way as to allow subjects to "ask for" pictures as well as for periods of pause time. It might be that the most efficient use of the subject's time can best be ascertained by allowing him such choices. For example, equipment could be arranged such that a subject who was listening to discourse could obtain brief access to a related picture by pressing a button once, or more extended access by pressing the button several times at short intervals. A procedure of this kind in studying the contribution of the audio and video portions of televised instruction was used successfully in a study by Ksobiech (1976).

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Table 1

Mean Nunber of Correct Answers to the Eight Questions for Combinations of Values of the Four Independent Variables

	Rate	225 wpm		300 wpm	
Presentation Condition	Pause Time / Question Type	4 sec	0 sec	4 sec	0 sec
Discourse Alone	8 Redundant	4.00	5.83	2.83	2.33
	8 Contextual	5.33	6.67	3.33	2.50
Discourse and Pictures	8 Redundant	7.17	7.17	5.33	6.33
	8 Contextual	5.83	6.00	5.33	3.50

Table 2

Analysis of Variance for Number of Correct Answers to the Eight Questions

Source of Variation	SS	df	MS	F
Between Cells	244.41	15	16.29	
Pause (A)	0.51	1	0.51	<1
Rate (B)	102.10	1	102.10	40.68*
Presentation Condition (C)	71.76	1	71.76	28.59*
Question Type (D)	2.35	1	2.35	<1
AB	11.34	1	11.34	4.52*
AC	2.35	1	2.35	<1
AD	4.59	1	4.59	1.83
BC	10.01	1	10.01	3.99*
BD	1.25	1	1.25	<1
CD	25.01	1	25.01	9.96*
ABC	4.59	1	4.59	1.83
ABD	3.02	1	3.02	1.20
ACD	0.51	1	0.51	<1
BCD	1.26	1	1.26	<1
ABCD	3.76	1	3.76	1.50
Within Cells	200.50	80	2.51	
Total	441.91	95		

*Statistically Significant

Table 3

Mean Number of Correct Answers to the Eight Questions for Combinations of Values of Rate and Length of Pause

Pause Time	4 sec	0 sec
Rate		
225 wpm	5.58	6.42
300 wpm	4.21	3.67

Table 4

Mean Number of Correct Answers to the Eight Questions for Combinations of Values of Presentation Condition and Rate

Rate	225 wpm	300 wpm
Presentation Condition		
Discourse Alone	5.46	2.75
Discourse and Pictures	6.54	5.13

Table 5

Mean Number of Correct Answers to the Eight Questions for Combinations of Values of Presentation Condition and Question Type

Question Type	8 Redundant	8 Contextual
Presentation Condition		
Discourse Alone	3.75	4.46
Discourse and Pictures	6.50	5.17